Docket No.: 2328-053 PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of	:
Tuquiang NI et al.	: Confirmation No. 5171
U.S. Patent Application No. 09/821,753	: Group Art Unit: 1763
Filed: March 30, 2001	: Examiner: Luz L. ALEJANDRO

For: PLASMA PROCESSING METHOD AND APPARATUS WITH CONTROL OF PLASMA EXCITATION POWER

Commissioner For Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION OF ANDREW D. BAILEY III, Ph.D.

I, Andrew D. Bailey III, Ph.D., hereby declare as follows:

1. Exhibit 1 is an accurate statement of my education, work experience, honors, publications, presentations and abstracts and issued United States Patents. As part of my work experience, I have worked closely with those of ordinary skill in the art relating to plasma processing of work pieces and have supervised many persons of ordinary skill in the art in the plasma processing of work pieces. As a result of my work experience, I am knowledgeable of those of ordinary skill in the art in the plasma processing of work pieces. I am also regarded by my peers as an expert in the technology relating to plasma processing of work pieces. Many of the publications listed in Exhibit 1 are publications in refereed journals, and as such, were subject to peer review prior to publication.

2. I have carefully read the referenced application as filed, the claims presently pending in the referenced application, the Office Action of March 9, 2006, and the Bhardwaj et al. reference, USP 6,051,503, primarily relied on in the Office Action.

3. My review of the referenced application, as originally filed, finds support for the requirement of claims 1 and 17 for "the AC etchant plasma always being the dominant material applied to the work piece while the feature is being formed."

(a) Page 5, lines 26-28 and claim 8, page 19 indicate that in the preferred embodiment, a gas species is ionized into a plasma that etches the material and that the preprogrammed gradual power change and the species are such that the material is shaped so a rounded corner is formed in the material as a result of the etching. This statement enables one of ordinary skill in the art to understand that the feature is the rounded corner. One of ordinary skill in the art would understand from the statement that an AC etchant plasma is always the dominant material applied to the work piece while the rounded corner is being formed.

(b) Page 6, lines 1 and 2 and claims 9 and 10, on page 19 of the application as filed, state that in one specific embodiment, the etching forms a trench wall including the rounded corner, which in one embodiment is at an intersection of a wall and a base of a trench. One of ordinary skill in the art would understand, from this statement, that an etchant is a dominant material that forms a trench wall including a rounded corner, which one of ordinary skill in the art would equate with a feature, particularly since page 6, lines 1-2 and claims 9 and 10 indicate the rounded corner is at an intersection of a wall and a base of a trench.

(c) Page 6, lines 26-29, of the application as filed indicates Figure 5 is a schematic diagram of a cross section of an illustrative semiconductor wafer prior to etching and Figure 6 is a schematic diagram of the wafer illustrated in Figure 5 after it has been etched in accordance with a specific embodiment of the invention. Such a statement would lead one of ordinary skill in the art to understand that the changes that occurred in transforming the structure of Figure 5 into the structure of Figure 6 was caused by etching being a dominant material applied to the wafer.

(d) Page 8, lines 20-23, in paragraph 30 of the application as filed, indicates there usually are several gas sources of different species, e.g., etchants, such as SF_6, CH_4, C_{12}

and HBr, dilutants such as Ar or He and O_2 as a passivation gas. One of ordinary skill in the art would interpret this to mean that a feature could be formed exclusively from the etchant gas which would be a dominant gas to form the material, or as a combination of the etchant gas, the dilutant gas and/or the oxygen passivation gas. Based on the other statements in the application as filed about etching occurring to form the trench walls and rounded corner, one of ordinary skill in the art would know that the etchant gases referred to at page 8, lines 20-23, were the dominant gases in the etching operations.

(e) Page 9, lines 16 and 17 indicates that an end point is detected of the process (either etching or deposition) that plasma 50 is performing on work piece 54. This statement would be interpreted by those of ordinary skill in the art as detecting the end of an etching process dominated by an etchant gas or the end of a deposition step dominated by a deposition gas, such as oxygen serving as a passivation gas.

(f) Page 14, line 28-page 15, line 2 indicates Figures 5 and 6 are respectively schematic drawings of an illustrative semiconductor structure prior to and subsequent to etching operations in accordance with one embodiment of the present invention. Such a statement would be interpreted by one of ordinary skill in the art as a transformation occurring from the structure of Figure 5 to the structure of Figure 6 as a result of an etchant gas being the dominant material applied to the semiconductor structure.

(g) Page 15, line 8-page 16, line 20 refers only to etching of the structure of Figure 5 to get slightly above the trench final base 214, as illustrated in Figure 6. Page 16, lines 20-23 indicate the final etch operation of silicon substrate 202 between point 212 and base 214 is performed in such a manner as to achieve rounded edges 216 between point 212 and base 214. This statement indicates to one or ordinary skill in the art that an etching operation, using an etchant gas as the dominant material, results in the production of rounded edge 216.

(h) Page 16, line 26-page 17, line 1 states microprocessor 201 has a memory system that performs the final etch operation for 15 seconds. During the 15 second final etch operation a suitable mixture of HBr/O_2 constantly flows from source 68 into

chamber 40. One of ordinary skill in the art would interpret such a statement to mean that the etchant HBr is dominant over the O_2 passivation gas because the memory system is stated to perform the final <u>etch</u> operation.

(i) Page 17, lines 4 and 5 indicates that after base 214 has been reached, the etchant gases are purged from the chamber. Such a statement would lead one of ordinary skill in the art to assume that the etchant gases were the dominant gases applied during the formation of the features involved in etching the structure of Figure 5 into the structure of Figure 6.

4. I do not agree with the statement in the Office Action that Bhardwaj et al. discloses converting a gas species into an AC etchant plasma that is either the dominant material or the only material that is continuously applied to a work piece while a feature of the work piece is being formed. The Office Action erroneously states that a portion of the side wall of a trench can be considered as an exemplary feature.

(a) Each of independent claims 1, 29, 30 and 31 of Bhardwaj et al. is concerned with a method of etching a feature in a semiconductor substrate. To form the feature, the substrate is subjected to a cyclical process including plural successive process cycles. Each of the successive process cycles includes a first process of reactive ion etching and a second process of depositing a passivation layer by chemical vapor deposition. Column 1, lines 4-13, of Bhardwaj et al. indicates that one possible feature is a trench wall, not a portion of the side wall of a trench.

(b) Based on the foregoing, it is clear to me, as an expert in the technology, that Bhardwaj et al. does not disclose converting a gas species into an AC etchant plasma that is either the dominant or only material that is continuously applied to a work piece while a feature of the work piece is being formed. The entire thrust of the Bhardwaj et al. patent is to form a feature by alternately etching and depositing materials, as indicated, for example, by the waveforms of Figure 7, wherein the first, fourth and seventh columns are associated with etching, the second and fifth columns are associated with deposition, and the third and sixth columns are associated with pump out of gases. Figure 7 indicates

that during the etch steps, the coil power and the bias power remain constant and that the coil and bias power also remain constant during the etch steps. The waveforms of Figure 9(i) and 9(ii) indicate that bias power changes abruptly between the etch and deposition steps. The RF bias is high during the deposition steps when pressure is low, and is low during the etch steps, when pressure is high. Column 9, lines 47-51 indicates the bias changes from low to high as the cycle changes from deposition as etch, respectively, in synchronism with pressure changes from low to high. These alternate etch and deposition steps occur during etching of a feature, particularly a side wall, as discussed in column 1, lines 4-13 and as set forth in the independent claims.

(c) The discussion in Bhardwaj et al., column 8, line 27-column 9, line 34 indicates the importance Bhardwaj et al. ascribed to the alternate etching and deposition steps to form a feature. This portion of Bhardwaj et al. indicates the problems associated with the prior art, as represented by Figure 3, in forming a silicon trench only by etching. The paragraph bridging columns 8 and 9 is particularly relevant because it discusses the importance of the passivation, i.e., deposition, step.

(d) Based on the foregoing, Bhardwaj et al. does not form a feature of a work piece by converting a gas species into an AC etchant plasma that is always the dominant material applied to the work piece while the feature is being formed, wherein the amount of AC power applied to the plasma during etching of the work piece to form the feature gradually changes and a gradual transition in the shape of the material in the work piece being processed occurs in response to the gradual power change that occurs during the gradual transition in the shape of the material. While Bhardwaj et al. discloses gradual power change, the gradual power change is always associated with alternate application of etchant gas and deposition gas to the work piece during formation of the feature.

(e) In addition, Bhardwaj et al. does not form a feature of a work piece by converting a gas species into an AC etchant plasma that is always the dominant material applied to the work piece, wherein the amount of AC power applied to the plasma during etching of the work piece gradually changes and a gradual transition in the shape of the

material in the work piece being processed occurs in response to the gradual power change that occurs during the gradual transition in the shape of the material.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine, or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

DATED this 5 day of June, 2006, at Fremont CA.

Andrew D. Bailey III, Ph.D.

EXHIBIT 1 – ANDREW D. BAILEY III, PH.D. DECLARATION

Lam Research Corporation
4650 Cushing Parkway CA-3
Fremont, CA 94538-6470
(510) 572 - 2200
andrew.bailey@lamrc.com

5167 Northway Road
Pleasanton, CA94566
(925) 461 - 8642

Education

Ph.D. Applied Physics 2/93
Experimental Plasma Physics
California Institute of Technology, Pasadena
Thesis Research: Used planar laser induced fluorescence to measure drift wave ion velocity field in a tokamak plasma and addressed relationship between stochastic particle trajectories and velocity distribution functions.
Advisors: Dr. Paul M. Bellan with Dr. Raul A. Stern (U. of Col. - Boulder)
B.S. Applied Mathematics, Engineering and Physics with Honors 5/87
University of Wisconsin - Madison GPA 3.9/4.0 Phi Beta Kappa

Experience

Technical Director 8/00 to present
Process Technology, New Product Development
Lam Research Corporation,
Fremont, CA

Responsible for managing the Plasma Process Technology engineering group for a number of Lam's emerging plasma processing products including hardware and applications on advanced plasma processing materials and integration flows internally, with industry partners and customers, e.g., 300mm Cu dual damascene, porous low-dielectric constant material, SiLK, organosilicate glass (OSG) etching, hi-dielectric constant material gate applications, magnetic random access memory (MRAM). Sponsor research activities in array multidisciplinary areas to support advanced capabilities: multivariate data analysis, university programs, rf technology and design.

Also responsible for process development on dual frequency confined (DFC) technology used in Lam 2300 Exelan 200/300mm plasma processors sold to leading semiconductor companies worldwide.

EXHIBIT 1 – ANDREW D. BAILEY III, PH.D. DECLARATION

Program Manager New Product Dev. 2/98 to 8/00
Lam Research, Fremont, CA

Built group of 8 process engineers working on range of new products and programs: ADP, patents, novel documentation strategies, dielectric etch, low-dielectric, Joint Product Development Programs 300mm dual damascene

Director Process Development 9/97 to 2/98
Trikon Technologies, Chatsworth, CA

Responsible for all demonstration activity, eleven etch tools (21 modules), lab, supervised 14 engineering personnel during turbulent corporate period.

300mm Etch Program Manager 8/97 to 2/98
Trikon Technologies, Chatsworth, CA

Plan Trikon's 300mm etch program. Responsible for product development, engineering, process transfer, marketing, Supervise development team and form engineering team to design 300mm module. Work with outside suppliers of critical components. Manage group of people including a Ph.D., engineer personnel and those involved in planning and marketing.

MØRI Metal Etch Product Manager 1/97 to 7/97
Trikon Technologies, Chatsworth, CA (merger PMT and Electrotech)

Supervised 5 people and was responsible for field process during tool startup, demonstrations, presentations, field process support, development of hardware and software and integration of new Anti-Corrosion Module, manage improvement of vapor delivery system for production. Managed a number of engineering projects in response to field requirements. Coordinated testing and improvement of electrostatic chuck for use at cryogenic temperatures. Brought performance of vapor delivery system to production, handed off manufacturing engineering. Managed integration of Electrotech high pressure module into Renaissance platform including software, mechanical and electrical systems as well as detailed process characterization.

Metal Etch Process Manager 1/96 to 1/97
Plasma and Materials Technologies

Managed formation and growth of Metal Etch Development Group involving plasma etching. Responsible for customer demonstrations, development of Tungsten interconnect etch process. Support introduction of Al and Tungsten etch tools into production. Managed Al etch process development team having three dedicated engineers. Transferred Al etch process to new Pinnacle 8000R platform.

Member of Technical Staff 8/94 to 1/96

PMT, Research and Development

Developed Al etch process for PMT's MØRI helicon plasma source. Demonstrated superior Al to photoresist selectivity using $Cl_2/BCl_3/N_2$ etch processes on 6 and 8" wafers using Pinnacle 8000 cluster tool with MØRI helicon plasma source. Instrumental in sales to key customers in Korea (LGS, Hyundai) and Japan (Sharp). Improved data analysis software for Langmuir probe product. Demonstrated hydrogenation of poly-silicon TFT gates (Xerox). Studied strip and corrosion issues, LLS with Gary Selwyn

Postdoctoral Member of Technical Staff 3/93 to 8/94

Display Research Department — Dr. Richard A. Gottscho

AT&T Bell Laboratories, Murray Hill — Department Head

Studied low temperature silicon nitride deposition and subsequent processes for active matrix liquid crystal displays on plastic substrates. Used *in situ*, real time, attenuated total reflection Fourier transform infrared spectroscopy to study film and interface properties of SiN_x and other semiconductors. Studied aspect ratio dependent scaling of Si and GaAs trench etch rates in an ECR plasma reactor. Included etch inhibitor in ion-neutral synergy model to quantitatively describe data at different substrate temperatures. Supervised undergraduate summer intern.

Research Assistant 9/87 – 2/93

U.S. Dept. of Energy Magnetic Fusion Science Fellow 9/87 – 9/90

California Institute of Technology, Pasadena

Developed first plasma planar laser induced fluorescence diagnostic. Made first two-dimensional images of the plasma ion fluid velocity field. Found qualitative agreement between measured flow field of stochastically heated ions in a drift wave and calculations of the two-fluid drift approximation. Observed ion temperature oscillations coherent with the drift wave. Developed new theoretical viewpoint to study the effect of stochastic single particle dynamics on macroscopic plasma parameters.

Research Assistant Summer 1989

Los Alamos National Laboratory, NM

Wrote software for quantitative analysis of film images from soft x-ray pinhole camera on FRX-C/LSM field reversed configuration. Developed upgrade of x-ray camera to capture images directly with CCD camera for real time analysis of FRX plasma discharges. Collaborated with Dr. Dan Taggart under group leader Dr. R. E. Siemon.

Research Assistant 5/86 – 9/87

University of Wisconsin, Madison

Studied plasma wakes and double layers in Dr. Noah Hershkowitz's lab.

Freelance Programmer summers/vacations 4/82 – 6/85

Programmed math and science educational software for Control Data and Addison-Wesley

<u>Teaching Experience</u>

AT&T Mentor Program '93

AT&T Bell Laboratories
Taught semiconductor processing and ATR-FTIR to an undergraduate researcher while guiding her research project in our lab.

Summer Undergraduate Research Fellowship Supervisor '90 – '92
California Institute of Technology
Guided progress of three undergraduates during their research projects in our lab.

Teaching Assistant 9/91 – 6/92
California Institute of Technology
Lectured and graded homework for graduate plasma physics course.

Teacher 9/89 – 5/90
Caltech's Secondary Schools Science Project
Taught optics course to advanced high school students.

Technical Experience

Software — developed systems of programs for experimental control (custom and CAMAC), for data acquisition, analysis and display, for physical, dynamic and optical modeling, for digital image processing and for science education

Lasers — operated and maintained copper vapor, doubled Nd-YAG and dye lasers; built flashlamp pumped dye laser

Optics — designed novel low f/\# imaging system with multianode microchannel plate photomultiplier; set up and used variety of optical systems: x-ray pinhole camera, optical multichannel analyzer, spectrometer, scanning etalon, interferometer, CCD camera, photomultiplier, electro-optic modulator, photodiodes

Electronics — built TTL timing and control circuits, analog detection circuits, dc and gated high voltage circuits; maintained pulsed power systems

Other Skills — used and maintained UHV and standard vacuum systems; experienced with machine shop skills; proficient with $\TeX$, DesignCAD, Windows, Word, Origin, Excel, Project, Powerpoint

Honors

Lam Vista Award	7/04
Athletic Board Scholar (top GPA of all graduating varsity athletes at UW-Madison)	6/87
Trewartha Honors Undergraduate Research Grant	'86 – '87
Prof. Linnaeus Wayland Dowling Scholarship (math)	'85 – '87
Irma L. Newman Scholarship (math)	'85 – '86
Undergraduate Summer Institute (Livermore Natl. Lab., Hertz Fndtn., UC-Davis)	8/86

Publications

G. Tynan, A. D. Bailey III, G.A. Campbell, R. Charatan, A. de Chambrier, G. Gibson, D. J. Hemker, K. Jones, A. Kuthi, C. Lee, T. Shoji, M. Wilcoxson, "Characterization of an azimuthally symmetric helicon wave high density plasma source," J. Vac. Sci. Technol. A **15(6)**, 1-8 (1997).

G. S. Selwyn and A. D. Bailey III, "Particle contamination characterization in a helicon plasma etch tool," J. Vac. Sci. Technol. A **14**, 1 (1996).

A. D. Bailey III, P. M. Bellan and R. A. Stern, "Poincaré maps define topography of Vlasov distribution functions consistent with stochastic dynamics," Phys. Plasmas **2**, 1 (1995).

A. D. Bailey III and R. A. Gottscho, "Aspect ratio independent etching: fact or fantasy?," Jpn. J. Appl. Phys. **34**, 2083-2088 (1995).

A. D. Bailey III and R. A. Gottscho, "Real-time monitoring of silicon nitride composition during plasma enhanced chemical vapor deposition," Jpn. J. Appl. Phys. **34**, 2172-2181 (1995).

A. D. Bailey III, M. C. M. van de Sanden, J. A. Gregus and R. A. Gottscho, "Scaling of Si and GaAs trench etch rates with aspect ratio, feature width, and substrate temperature," J. Vac. Sci. Technol. B **13**, 92 - 104 (1995). Erratum **15**, 373 (1997).

A. D. Bailey III, R. A. Stern and P. M. Bellan, "Measurement of coherent drift-wave ion-fluid velocity field when ion dynamics are stochastic," Phys. Rev. Lett. **71**, 3123-3126 (1993).

M. R. Brown, A. D. Bailey, III, P. M. Bellan, "Characterization of a spheromak plasma gun: The effect of refractory electrode coatings," J. Appl. Phys. **69**, 6302 – 6312 (1991).

E. A. Crawford, D. P. Taggart and A. D. Bailey, III, "Soft x-ray pinhole imaging diagnostics for compact toroid plasmas," Rev. Sci. Instrum. **61**, 2795 – 2797 (1990).

D.J. Rej, M. Tuszewski, D.C. Barnes, R.D. Milroy, A.D. Bailey, G.A. Barnes, M.H. Baron, R.E. Chrien, J.W. Cobb, E.A. Crawford, A. Ishida, R.E. Siemon, J.T. Slough, J.L. Staudenmeier, S. Sugimoto, D.P. Taggart, T. Takahashi, R.B. Webster, B.L. Wright, "Tilt stability and compression heating studies of field-reversed configurations," Proceedings of the 13th IAEA International Conference on Plasma Physics and Controlled Nuclear Fusion Research (Washington, D.C. 1990).

D. P. Taggart, R. J. Gribble, A. D. Bailey, III, S. Sugimoto, "End on soft x-ray imaging of FRCs on the FRX-C/LSM Experiment", 11th US/Japan Compact Toroid Workshop Proceedings, 87 (1989).

A. D. Bailey, III, N. Hershkowitz, "Three Step Double Layers in the Laboratory," Geophy. Res. Lett. **15**, 99 – 102 (1988).

D. Diebold, N. Hershkowitz, A. D. Bailey, III, M. H. Cho, T. Intrator, "Emissive probe current bias method of measuring dc vacuum potential," Rev. Sci. Instrum. **54**, 270 (1988).

D. Diebold, N. Hershkowitz, T. Intrator, A. Bailey, "Self-similar potential in the near wake," Phys. Fluids **30**, 579 (1987).

Presentations/Abstracts

N. T. Mittadar, D. J. Economou, M. Nikolaou, J. Yi, A.D. Bailey III, P. Yadav, " Using High Fidelity Simulation in the Design of Experiments for Optimizing Etch Uniformity in Plasma Etching Reactors," AIChE Annual Meeting, November 2005.

N. T. Mittadar, M. Nikolaou, P. Yadav, A.D. Bailey III, D.J. Economou, "A hybrid approach to the design of experiments for efficient determination of optimal etch uniformity conditions," AIChE Annual Meeting, November 2004.

M. Nikolaou, A.D. Bailey III, "Multivariate reduced-rank statistical methods for the analysis of wafer uniformity patterns," International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM), April 2002.

S.P. Lohokare, M. Kennard, A.D. Bailey III, and D. Hemker, "Challenges in Plasma Etching of Low Volatility Materials for Advanced Memory Applications," presentation at Sixth International Symposium on Sputtering and Plasma Processing (ISSP), June 2001.

W. Collison, T. Ni, W. Jiang, B. Richardson, A. Bailey, D. Hemker, "300mm Etch Equipment Development," presentation at ECS International Semiconductor Technology Conference (ISTC), May 2001.

A. D. Bailey, III, J. A. Gregus, K. Krisch, P. Mulgrew, T. Polewik, and R. A. Gottscho "Low temperature silicon nitride deposition," talk given at Materials Research Society Flat Panel Desplay Materials Symposium, April 1994.

A.D. Bailey, III, M.C.M. van de Sanden, J.A. Gregus, E.S. Aydil and R. A. Gottscho, Aspect ratio dependent etching of GaAs and Si in an electron cyclotron resonance plasma reactor," talk presented at 40th Annual American Vacuum Society National Symposium, 1993.

A. D. Bailey, III, P. M. Bellan and R. A. Stern, "Drift wave ion velocity field measurement and the connection with Poincaré maps,'' Bull. Am. Phys. Soc. **37**, 1480 (1992).

A. D. Bailey, III, P. M. Bellan and R. A. Stern, "Observation of drift waves using laser induced fluorescence,'' Bull. Am. Phys. Soc. **36**, 2343 (1991).

A. D. Bailey, III, P. M. Bellan and R. A. Stern, "Initial operation of planar laser induced fluorescence diagnostic,'' Bull. Am. Phys. Soc. **35**, 2046 (1990).

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<u>Patents</u>

1. Temperature control system for plasma processing apparatus, US6,302,966, Oct01.
2. Method and apparatus for controlling the volume of a plasma – magnetic plasma screens, US6,322,661, Nov01.
3. Plasma processing systems – B field uniformity control, US6,341,574, Jan02.
4. Method and apparatus for producing uniform process rates – antenna and sandwich coupling window, US6,320,320, Nov02.
5. Antenna designs compensating for missing elements in real antennas, US6,518,705 Feb03.

6. Method and apparatus for producing uniform process rates – specific antenna design, US6,653,791, Nov03.
7. Method for quantifying uniformity patterns and including expert knowledge for tool development and control – multivariate uniformity metric, US6,723,574, Dec02.
8. A Method for Designing Antennas for Inductive Coupling Which Minimize Azimuthal Asymmetry, US6,744,213 May02.
9. System, method and apparatus for improved global dual-damascene planarization, US6,821,899 Nov04.
10. RF Plasma stability improvement, US6,838,832 Jan05.
11. Passive coils for plasma processing uniformity improvement, US6,842,147 Jan05.
12. Method for producing a semiconductor device - specific DCH antenna design US6,873,112, Mar05.
13. Method for quantifying Uniformity Patterns for Tool Development and Monitoring – Mass Analogy, US6,922,603, Jul05.
14. System, method and apparatus for improved global dual-damascene planarization (uniformity compensation focus), US6,939,796, Sept05.
15. Small Volume Plasma Process Chamber with Hot Inner Surfaces, US7,009,281, Mar06.
16. Plasma In-Situ Treatment of Chemically Amplified Resist, US7,022,611, Apr06.